Measuring predation rates and *Spartina alterniflora* stem densities to determine structure and function of restored salt marshes

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Abstract

To combat declines in salt marshes and loss of ecosystem services, restoration projects seek to restore both marsh structure and function. Because the plant material used in restorations may not be adapted to the local environment, it is unclear whether restored marshes function in the same ways as natural marshes. To compare the structure and function of restored and natural marshes, *Spartina alterniflora* surveys and field tethering experiments were performed in restored and natural marshes in Connecticut in the summer of 2018. Asian shore crabs (*Hemigrapsus sanguineus*) were tethered in two restored marsh areas of different age in Stratford, a naturally recolonizing marsh in Stratford, a natural reference marsh in Milford, and in unvegetated areas near these marshes. *S. alterniflora* density and stem height were measured at these locations, as well as algae and rock percent cover. Crabs survived best in the unvegetated locations in Milford, where algae cover was high, and in Stratford, where rock cover was high. Low crab survival in both the restored and natural marsh areas indicates that predators used these marshes as foraging grounds. *S. alterniflora* stem densities in the three year old restored marsh were similar to stem densities in the natural marshes, while stem densities were lower in the one year old restored marsh. *S. alterniflora* was shorter in both of the restored marsh areas compared to the natural marshes. Our results suggest that restored marshes can serve some of the same functions as natural marshes, even when their structures differ.

Introduction

Salt marshes are highly productive and valuable ecosystems that provide support, protection and feeding grounds for many other species[1]. Salt marsh ecosystem function has been severely impacted due to anthropogenic causes[2]. This has increased the need to restore salt marshes along coastlines worldwide[1]. It is unclear whether restored marshes function similarly to natural marshes. Plant material used for marsh restoration is often sourced from areas with different hydrological and ecological characteristics than the restoration site, which may affect the ability of newly planted shoots to acclimatize to the local environment[2]. Many restoration efforts involve monitoring recovery of marsh structure, but recovering marsh function is just as important. Many studies have examined nekton and marsh snail populations in restored marshes[2], but relatively few studies have documented dynamic processes such as predation in restored vs. natural marshes. Here, we examined both static measures of marsh structure and predation rates on invasive Asian shore crabs *(Hemigrapsus sanguineus*) in restored and natural fringing marsh areas at the mouth of the Housatonic River in Connecticut.

Objectives

1. Measure *Spartina alterniflora* stem height and density within the low, mid, and high intertidal zones of naturally occurring and restored marsh areas at a restoration site in Stratford, CT and a reference marsh in Milford, CT
2. Compare predation rates on invasive *Hemigrapsus sanguineus* (Asian shore crabs) in naturally occurring and restored marsh areas to assess the function of restored areas in comparison to naturally occurring marshes

Methods

Study Locations

1. Four locations within Stratford Point, CT. Reef Balls were installed at this site to abate wave energy and facilitate salt marsh restoration in 2014 and 2016 (Fig. 1):
   - Recolonizing marsh (regrowth of *S. alterniflora*)
   - Unvegetated area
   - Restored marsh planted in 2014 and augmented in 2015
   - Restored marsh planted in April 2017 (adjacent to the 2015 planting area)
2. Two locations within a reference marsh at Milford Point (Milford, CT)
   - Unvegetated mud area
   - Marsh area

Tethering Experiment

Ten *Hemigrapsus sanguineus* tethers were deployed in each location at low tide (Figs. 2 & 3). Crab survival was assessed after 24 hours.

Spartina alterniflora Survey

At each location in Stratford, we ran two 60-m transects parallel to the shore in each intertidal zone (low, mid, high) and counted the number of stems within ten randomly placed 0.25 m^2 quadrats along each transect. We also measured the height of the five tallest shoots within each quadrat and calculated the mean stem height. Since the naturally recolonizing marsh in Stratford is narrower than the other marsh areas, we ran one 20-m transect there and collected data from ten evenly spaced 0.25 m^2 quadrats as described above.

Algae Survey

We measured percent algal cover in five haphazardly placed 0.25 m^2 quadrats that were divided into 100 equally sized squares in each location where crabs were tethered.

Fig. 1. Restored marsh behind Reef Balls at Stratford, CT.

Fig. 2. Tethered Asian shore crab.

Fig. 3. Tether in mud area in Milford, CT.

Results

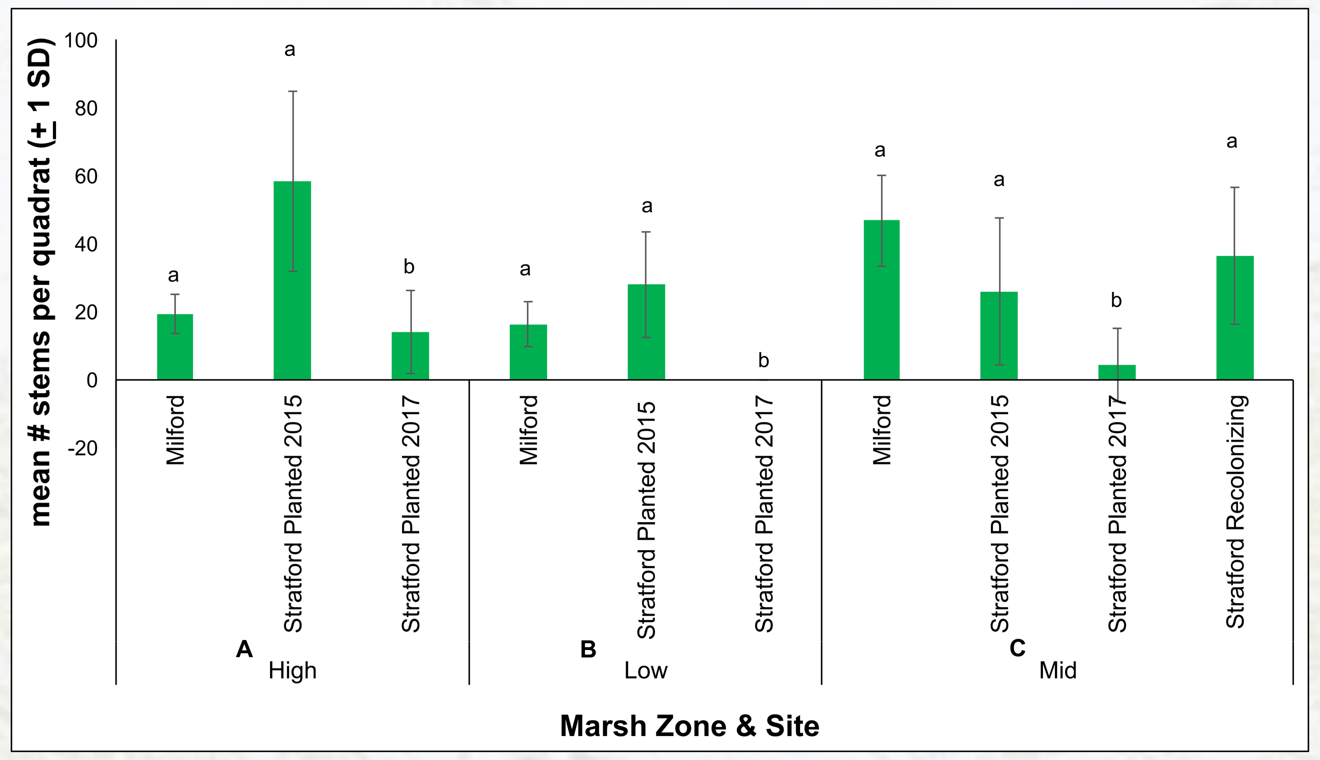

Figure 4. Mean number of stems per quadrat ($\pm$ 1 SD) in the low, mid, and high intertidal zones in restored (Stratford Planted 2015, Stratford Planted 2017) and natural marsh sites (Milford, Stratford Recolonizing). Different lowercase letters over the bars indicate significant differences between locations. Different uppercase letters next to the intertidal zone indicate significant differences between marsh zones. Two-Way ANOVA: site $F_{3,90}$=23.109, p<0.001; marsh zone $F_{2,90}$=8.426, p<0.001; site*marsh zone $F_{4,90}$=9.943, p<0.001).

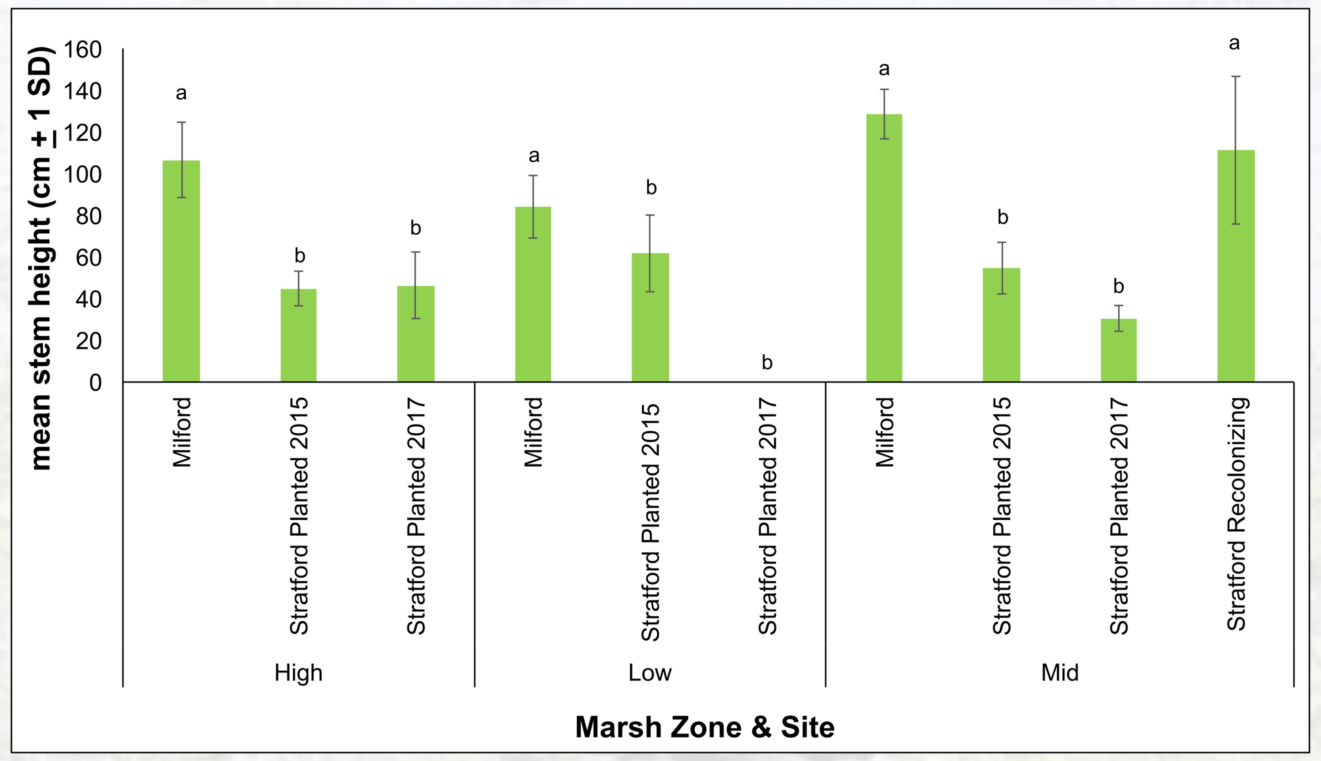

Figure 5. Mean stem height (cm $\pm$ 1 SD) in the low, mid, and high intertidal zones in restored (Stratford Planted 2015, Stratford Planted 2017) and natural marsh sites (Milford, Stratford Recolonizing). Different lowercase letters over the bars indicate significant difference between locations. No significant difference in mean stem height was detected among marsh zones, but there was a significant interaction between site and marsh zone. Two-Way ANOVA: site $F_{3,70}$=52.262 , p< 0.001; marsh zone $F_{2,70}$= 2.421, p=0.096; site*marsh zone $F_{3,70}$= 7.971, p<0.001).

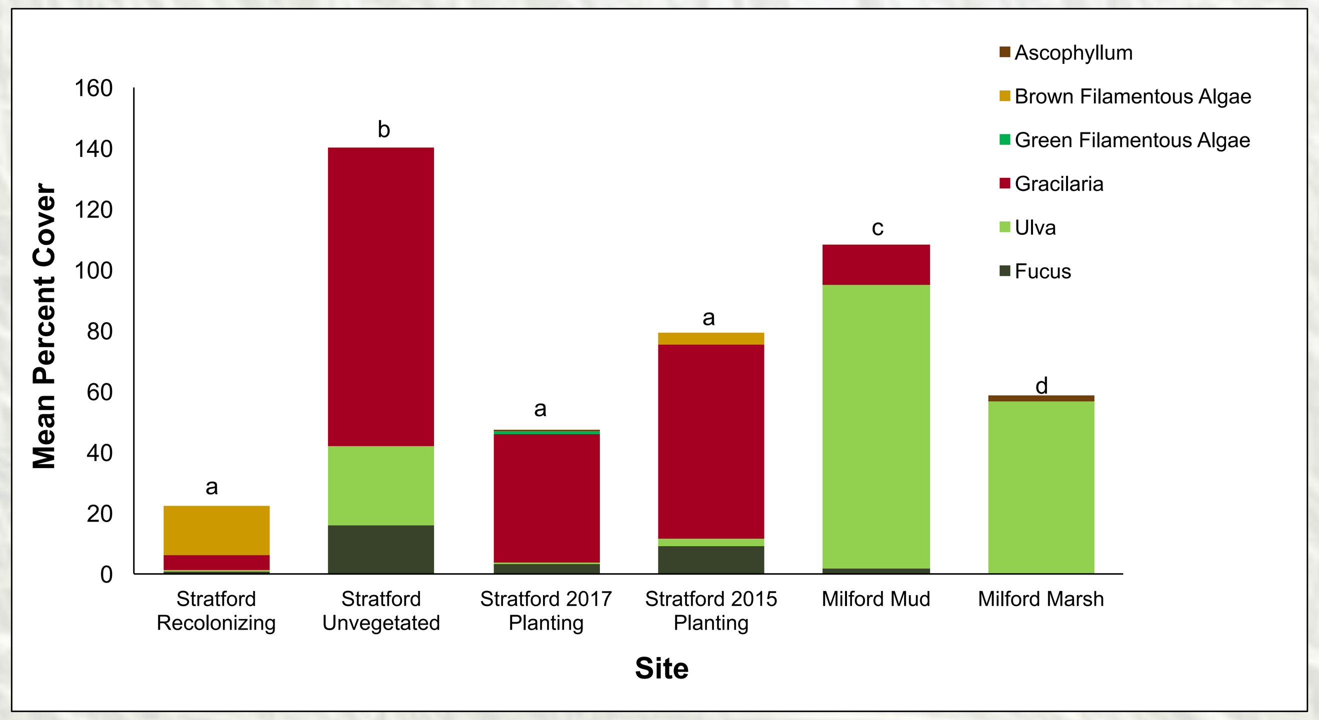

Figure 6. Mean percent algal cover in restored (Stratford Planted 2015, Stratford Planted 2017) and natural marsh locations (Milford Marsh, Stratford Recolonizing), along with unvegetated areas at the restoration site (Stratford Unvegetated) and the reference site (Milford Mud). Different letters over the bars indicate significant differences in algal communities between those locations (ANOSIM: R= 0.65, p= 0.001).

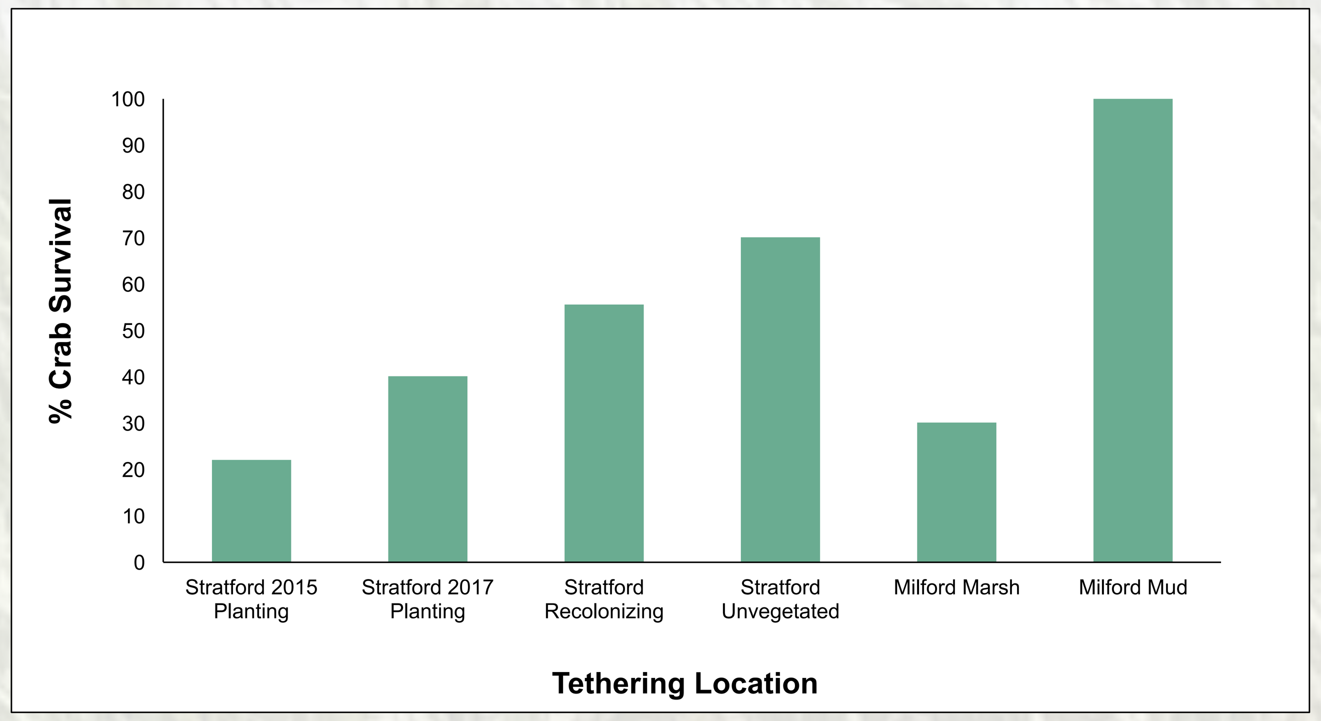

Figure 7. Percent survival of Asian shore crabs (*Hemigrapsus sanguineus*) tethered in restored (Stratford Planted 2015, Stratford Planted 2017) and natural marsh locations (Milford Marsh, Stratford Recolonizing), along with unvegetated areas at the restoration site (Stratford Unvegetated) and the reference site (Milford Mud). Crab survival differed significantly among these sites (X^2= 15.374, p<0.017).

Conclusions

***Spartina alterniflora* Metrics:** *S. alterniflora* stem densities in areas planted in 2015 were similar to those in the Milford reference marsh in all intertidal zones (Fig. 4). However, mean stem height was higher in the two naturally occurring marshes than in either of the restored areas (Fig. 5). The most recently planted marsh area (Stratford 2017 Planting) had both lower stem densities and shorter stems than the older marshes (Figs. 4 & 5).

Crab Survival: *Hemigrapsus sanguineus* survived best in the unvegetated locations where algal cover was high (Figs. 6 & 7). Notably, crab survival in both restored marsh areas was similar to that in the reference marsh in Milford (Fig. 7). As the restored marshes mature, algal and rock cover will likely decline, which may lead to greater predation on these invasive crabs and a subsequent reduction in their population. Low crab survival in both restored areas and the reference marsh in Milford indicate that these marshes functioned as foraging grounds for small crustaceans (Fig. 7).

Overall Restoration Trajectory: The restored marsh area planted in 2015 achieved similar stem densities to those in the natural marshes after only three years (Fig. 4). Although stem heights were shorter in both of the restored marsh areas compared to the natural marshes, they may eventually reach a stem height similar to that in Milford, since the naturally recolonizing area in Stratford has *S. alterniflora* stems that are similar in height to those in Milford (Fig. 5). Even though both its stem density and stem height differed from those in older marshes, the area planted in 2017 contained a similar algal community as the area planted in 2015 (Fig. 6), and crab survival in the most recent planting was similar to that in older marsh areas (Fig. 7). Overall, our results suggest that restored marshes can serve similar functions as natural marshes within a short time, even when their structures differ.

Literature Cited

1. Rezek RJ, Lebreton B, Boatwright BS, Pollack JB. 2017. PLoS ONE. 12(12): 1-23.
2. Beck J, Gustafson DJ. 2012. 11(4): 747-754.

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